

Simplex Ceramic Matrix Composite Turbine Blink Testing

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Matt Marsh

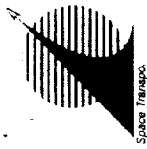
Space Transportation Directorate

TD 61

Subsystem and Component Development Department

Functional Design

Turbomachinery Team

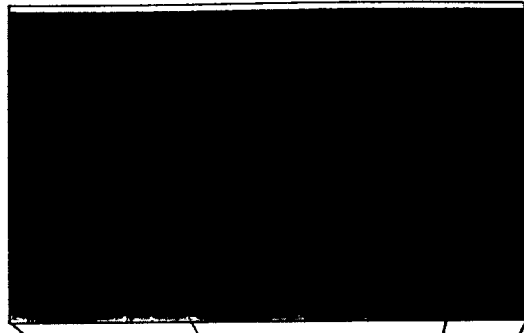
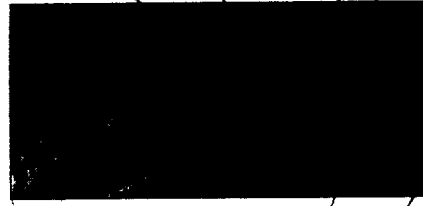


Ceramic Matrix Composite Turbine Blisk

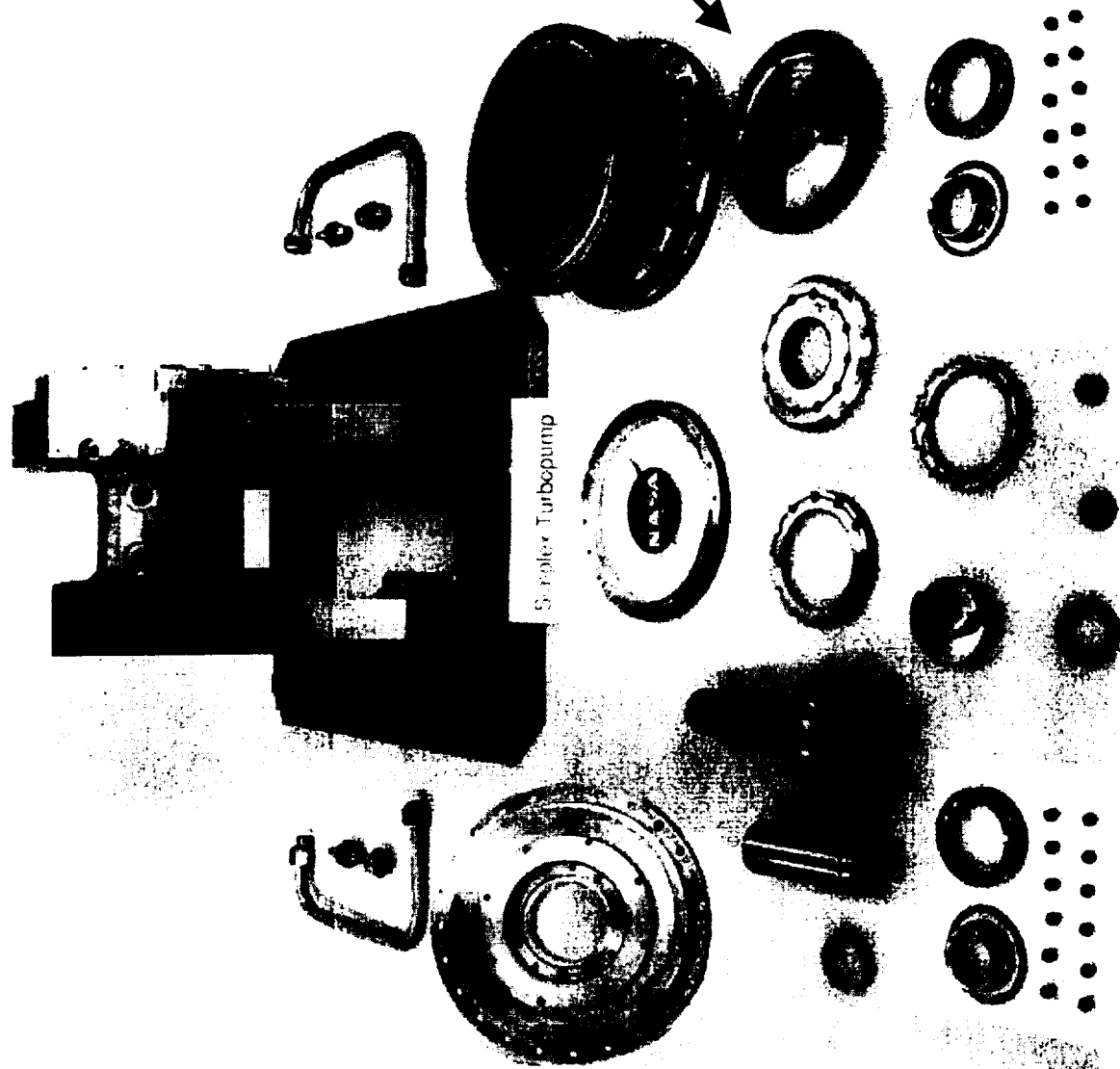


4 times lighter than typical metal turbines
25 % higher temperature range
10 times higher internal damping

Design



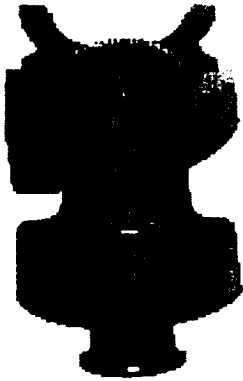
Ceramic Matrix Composite Turbine Blisk



Replace metal disc
with ceramic Blisk

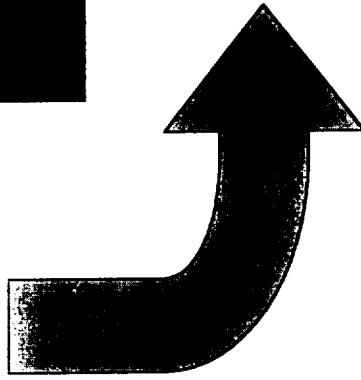
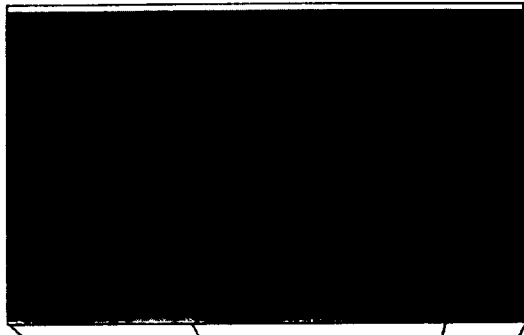


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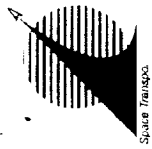
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Build

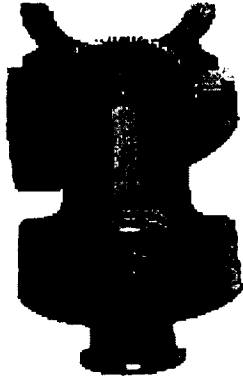




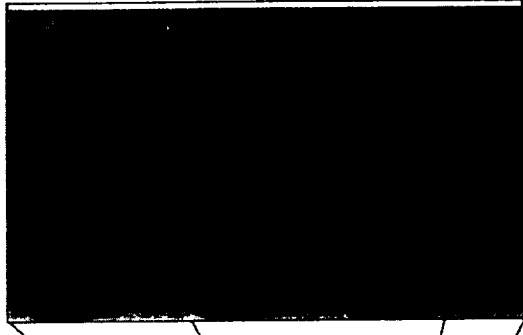
Ceramic Matrix Composite Turbine Blisk



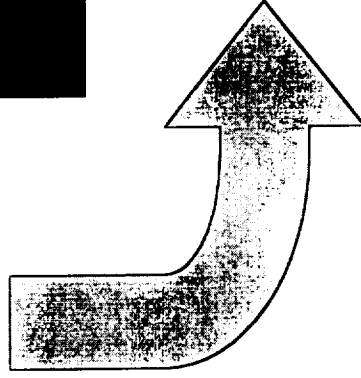
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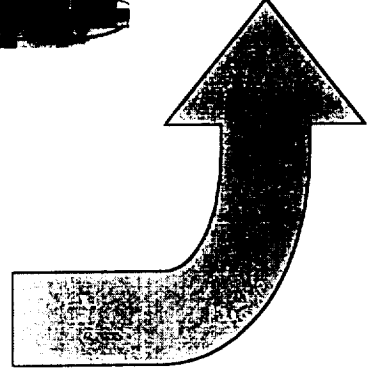
Design



Build



Test







Ceramic Matrix Composite Turbine Blisk



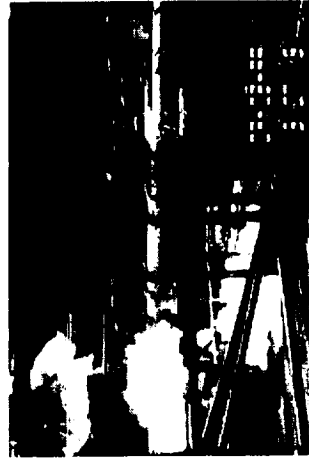
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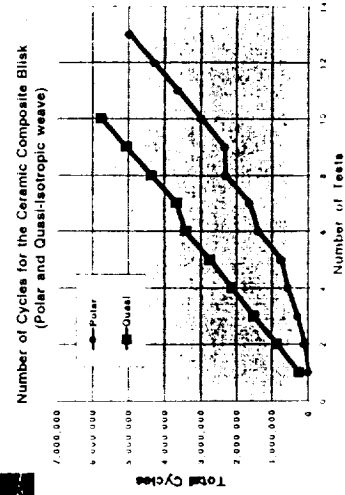


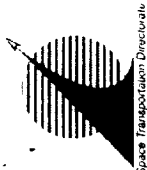
Build



Test

Results

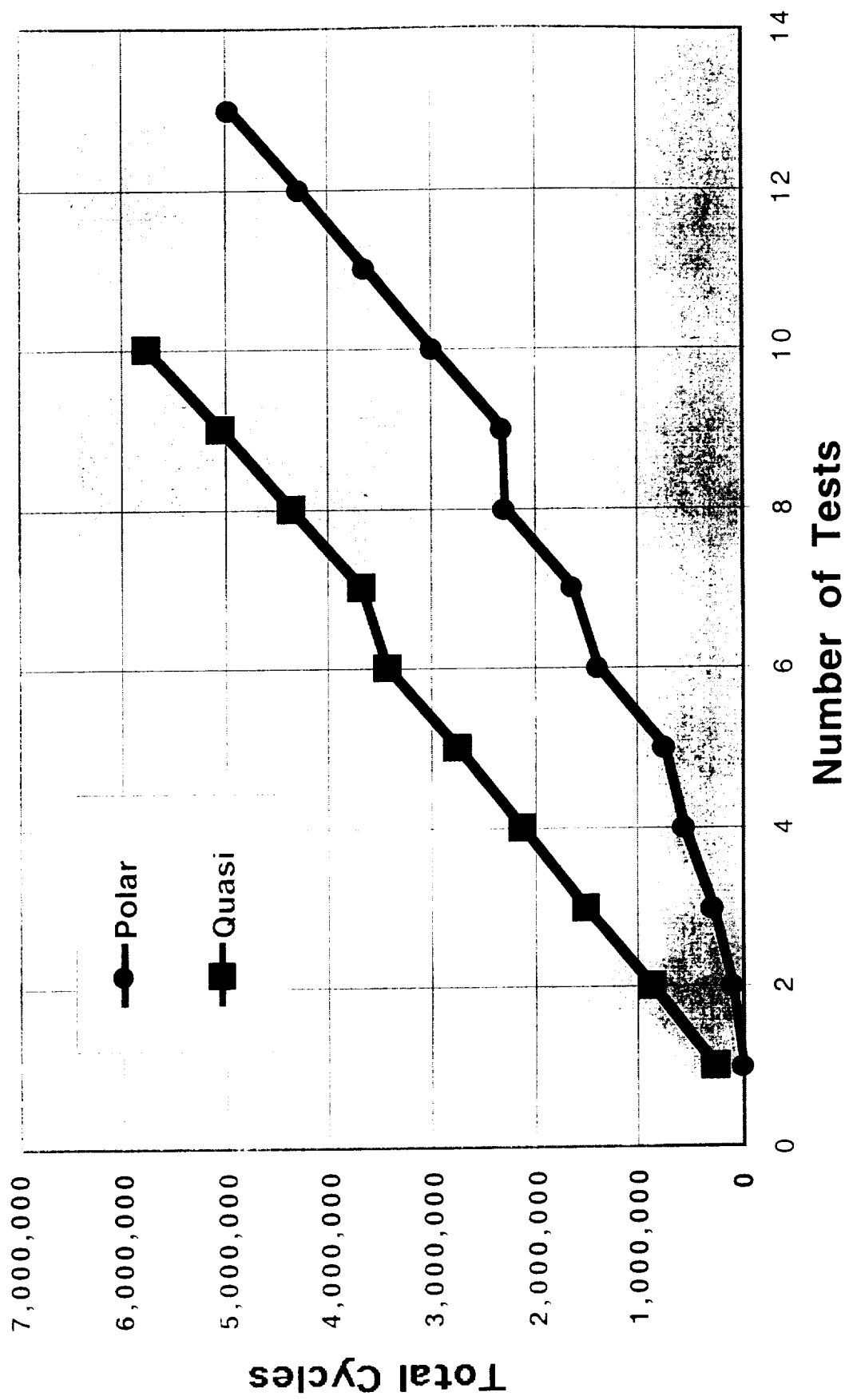




Ceramic Matrix Composite Turbine Blisk



Number of Cycles for the Ceramic Composite Blisk
(Polar and Quasi-Isotropic weave)



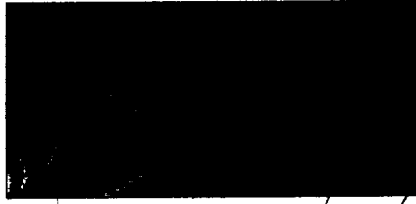
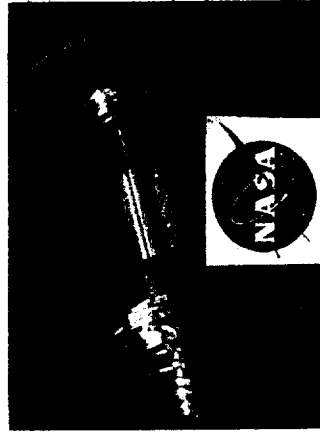


Ceramic Matrix Composite Turbine Blisk



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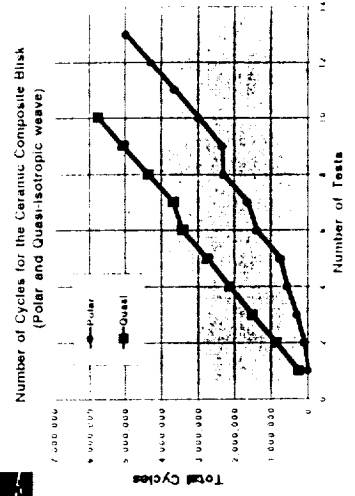
Design



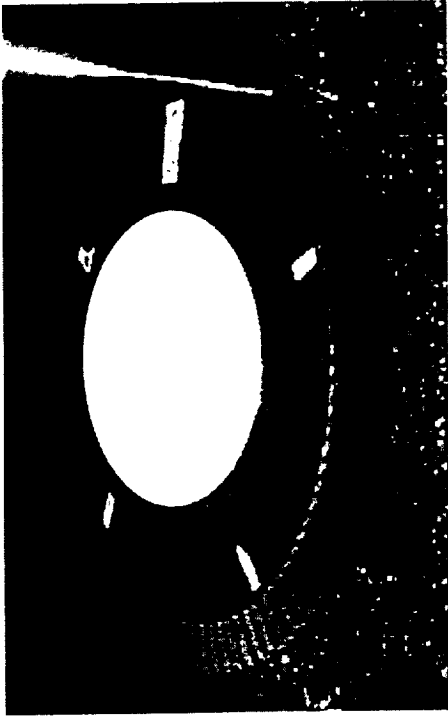
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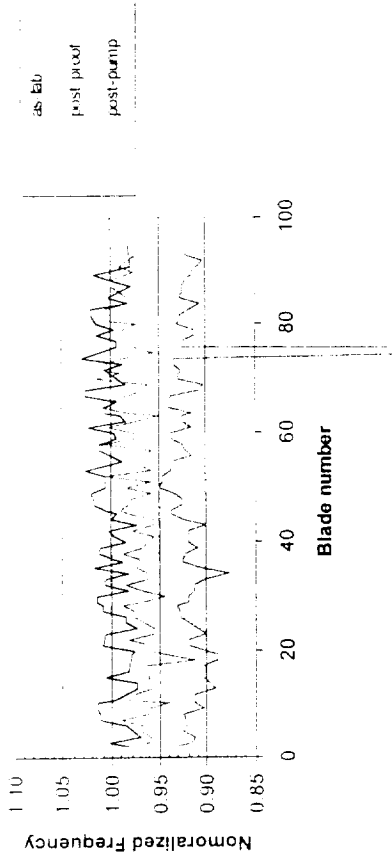
Test



Ceramic Matrix Composite (CMC) Material Damage Accumulation Determination Methodology using the Simplex Turbopump C/SiC Blisk



Blisk -004 Blade Normalized Frequency



- **Goals:** Develop a technique to easily monitor the health of a ceramic matrix composite
- **Objective:** Use change in modal characteristic to assess hardware life
- **Approach:** Perform C/SiC sample fatigue testing at AFRL interrupted by NDC.
 - Continue testing Simplex Blisk and perform blade NDE after each series
 - Correlate these samples with sectioned samples of Simplex Blisk
- **Status:**
 - Turbopump 2nd test series completed
 - Turbine Blisk 2nd NDE nearing completion
 - Coupon specimens fabrication completed
 - Plan to complete 3rd series pending funding

Ceramic Matrix Composite Turbine Blisk

STRESS ANALYSIS: Blisk Assessment (Blade Region) Revisited

Blade pressure profile calculated from Steady State CFD

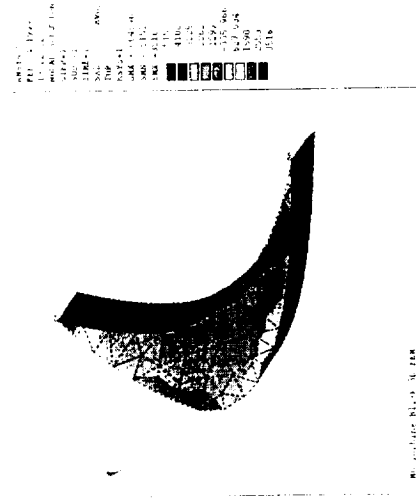
Unsteady loads assumed as a percent of steady loads accounting for partial admission

Safety Margins calculated were acceptable for metallic turbine configuration

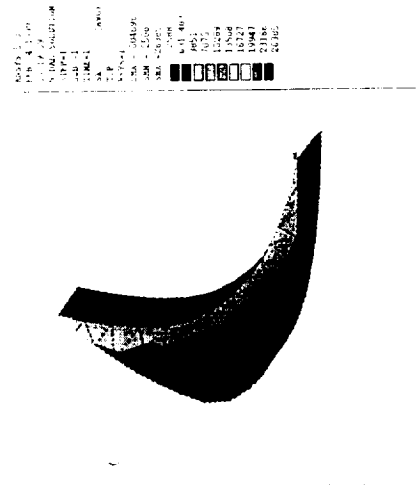
Safety Margins calculated for Ceramic Matrix Turbine configuration deemed minimum risk

Trailing edges seen as potential for loss of material (thin section)

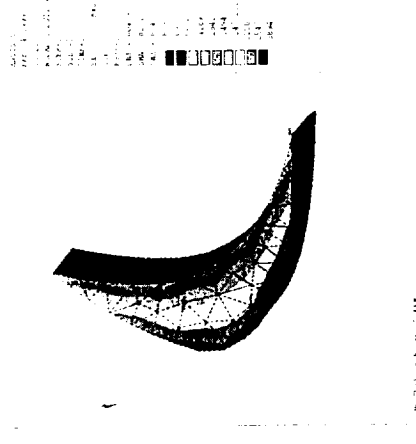
Post test inspections noted small leading edge and trailing edge material loss



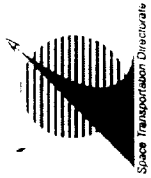
Interlaminar Shear Stress



Radial Stress



Across Ply Shear Stress



Ceramic Matrix Composite Turbine Blisk



Conclusions

Successfully demonstrated ten million cycles per blade on Polar Weave Ceramic Blisk

Demonstrated 5 million + cycles with crack through airfoil

Small change in material damping measured with modal testing

Building good database for High Cycle Fatigue life determination

Minimal damage to trailing edges throughout test series

No measurable difference in performance

Need to understand magnitude of unsteady blade loading

Correlate to damage accumulated in Polar Weave Blisk

Correlate to HCF coupon testing at various stress levels